

**FLIGHT SOFTWARE REQUIREMENTS  
DOCUMENT FOR THE  
THERMAL ION DYNAMICS EXPERIMENT (TIDE)**

SwRI Project 15-3348

Document No. 3348-FSRD-01  
Revision 1 Change 0

Prepared by:

D. Kloza  
D. Kloza, Software Engineer, SwRI

Date

12/15/95

Reviewed by:

K. Smith  
K. Smith, Software Engineer, SwRI

Date

12/18/95

Approved by:

R. Mielke  
R. Mielke, Quality Assurance, SwRI

Date

12/20/95

Approved by:

N. Eaker  
N. Eaker, Project Manager, SwRI

Date

12/20/95

Approved by:

D.T. Young  
D.T. Young, Co-Investigator, SwRI

Date

12/21/95

Approved by:

T. E. Moore  
T. E. Moore, Principal Investigator, MSFC

Date

09 Jan 95

SOUTHWEST RESEARCH INSTITUTE  
INSTRUMENTATION AND SPACE RESEARCH DIVISION  
6220 CULEBRA ROAD  
SAN ANTONIO, TX 78238

## REVISION RECORD

<sup>1</sup>Document "changes" require approval on this page. Document "revisions" require the re-release of the cover page with approval signatures.

## TABLE OF CONTENTS

1	INTRODUCTION .....	5
1.1	Scope .....	5
1.2	Applicable Documents .....	5
1.3	Overview .....	5
2	INSTRUMENT CONTROL .....	6
2.1	DPU Turn-On Sequence.....	6
2.1.1	RAM Tests .....	6
2.1.2	PROM Check .....	7
2.1.3	Software Download .....	7
2.1.4	HV and MCP Power Supply Initialization .....	7
2.1.5	Accumulation Period Initialization .....	7
2.1.6	Phase Shift Initialization .....	7
2.1.7	Watchdog Function .....	7
2.1.8	Energy Sweep Table Initialization .....	7
2.1.9	Mass Look-Up Table Initialization .....	7
2.2	Spacecraft Spin Synchronization (Accumulation Period Adjustment) .....	8
2.3	Data Acquisition Phase Shift .....	8
2.4	Power Supply Control .....	8
2.4.1	Default Automatic Sensitivity Control .....	8
2.4.2	Optional Automatic Sensitivity Control .....	8
2.5	Mass Selection .....	9
2.6	DPU Debug Mode .....	9
2.7	Plasma Source Instrument (PSI) Interface .....	9
3	DATA PROCESSING .....	9
3.1	Dump Mode .....	10
3.2	Science Mode .....	10
3.2.1	Dead Time Correction .....	10
3.2.2	Collapse Options .....	10
3.2.2.1	No Collapse (collapse option 0) .....	10
3.2.2.2	Energy Collapse (collapse option 1) .....	10
3.2.2.3	Medium Angular Resolution Collapse (collapse option 2) .....	10
3.2.2.4	Low Angular Resolution Collapse (collapse option 3) .....	11
3.2.2.5	Energy/Medium Angular Resolution Collapse (collapse option 4) .....	11
3.2.2.6	Energy/Low Angular Resolution Collapse (collapse option 5) .....	13
3.2.2.7	Calibration Supercollapse (collapse option 6) .....	13
3.2.3	Priority Ordering .....	13
3.2.4	Reporting Option .....	13
3.2.4.1	Truncated Reporting .....	13

3.2.4.2	Complete Reporting . . . . .	13
3.2.5	Lossy Compression . . . . .	13
3.2.6	Rice Compression . . . . .	16
3.2.7	Sub-modes . . . . .	16
3.2.7.1	Default Science Sub-mode . . . . .	16
3.2.7.2	High Angular Resolution Sub-mode . . . . .	16
3.2.7.3	High Time Resolution Sub-mode . . . . .	16
3.2.8	Scalar Data Efficiency Calculations . . . . .	17
3.2.9	Moment Calculations . . . . .	17
3.2.9.1	Polar Angle Centroid and Width . . . . .	17
3.2.9.2	Azimuth Angle Centroid and Width . . . . .	17
3.2.9.3	Energy Centroid and Width . . . . .	17
4	COMMANDING . . . . .	18
4.1	Pulse Commands . . . . .	18
4.2	Serial Data Command Formats . . . . .	18
5	TELEMETRY . . . . .	20
5.1	Housekeeping Data . . . . .	20
5.2	Science Data . . . . .	21
5.2.1	Spin Header . . . . .	21
5.2.1.1	Sync Word . . . . .	21
5.2.1.2	Spin Packet Length . . . . .	21
5.2.1.3	Mode ID . . . . .	21
5.2.1.4	Spin Counter . . . . .	21
5.2.1.5	Time Tag . . . . .	21
5.2.1.6	Continue Number . . . . .	22
5.2.1.7	MAGAZ . . . . .	22
5.2.1.8	MAGEL . . . . .	22
5.2.1.9	Accumulation Period . . . . .	22
5.2.1.10	TOF Efficiency Numbers . . . . .	22
5.2.1.11	Moments . . . . .	22
5.2.1.12	Invalid Events . . . . .	22
5.2.1.13	Trickled Direct Events . . . . .	22
5.2.1.14	Commands Received Counter . . . . .	23
5.2.1.15	Data Product Counter . . . . .	23
5.2.1.16	Spin Header Checksum . . . . .	23
5.2.2	Data Product Packets . . . . .	23
5.2.2.1	Instrument Parameters Data Product . . . . .	23
5.2.2.2	Instrument Parameter Changes Data Product . . . . .	23
5.2.2.3	Direct Events Sector 0 Data Product . . . . .	23
5.2.2.4	Dump Data Product . . . . .	23

APPENDIX A. ROM Energy Sweep Tables . . . . .	22
APPENDIX B. Automatic Sensitivity Control Algorithms . . . . .	28
APPENDIX C. ROM Mass Look up Tables . . . . .	30
APPENDIX D. PSI Commands . . . . .	32
APPENDIX E. Dead Time Correction Algorithms . . . . .	34
APPENDIX F. Lossy Compression . . . . .	37
APPENDIX G. Moments Algorithm . . . . .	40
APPENDIX H. Serial Command List and Command Formats . . . . .	43
APPENDIX I. Housekeeping Data . . . . .	57
APPENDIX J. Spin Packet Format . . . . .	63
APPENDIX K. Instrument Parameter and Instrument Parameter Change Data Products . . . . .	65

## 1 INTRODUCTION

### 1.1 Scope

This document contains the flight software requirements for the Thermal Ion Dynamics Experiment (TIDE) on the Polar spacecraft. The purposes of the software described in this document are to interface with the spacecraft through commands and telemetry, to control the commandable elements of the TIDE instrument, and to process the data received from the TIDE sensor electronics. These tasks will be executed in the Data Processing Unit (DPU) produced by Southwest Research Institute (SwRI). The DPU contains two SA3300 microprocessors and associated digital circuitry.

### 1.2 Applicable Documents

#### GE

3282065      GGS General Instrument Interface Specification (GIIS)  
IS 3282162    GGS Instrument Interface Control Document (ICD) for TIDE instrument

#### JPL

79-22    Some Practical Universal Noiseless Coding Techniques

### 1.3 Overview

The objective of the TIDE investigation is to obtain complete distribution functions for each important mass species at the maximum feasible time, azimuth, polar angle, and energy resolution consistent with the available telemetry. In practice, a compromise must be struck between the resolution of the sampling variables in order to arrive at an effective operating mode. Modes will be provided that make it possible to shift the resolution tradeoff in favor of temporal, angular, or energy resolution for the full distributions. In addition, a set of reduced moments of each distribution collected during the Science Mode will be computed and reported.

The memory array into which the valid TOF events are to be accumulated provides storage for 32 Energies x 32 Azimuths x 7 Polar Angles x 5 Masses, plus scalar data (i.e., start singles, stop singles, start converts, time-outs, and resets). This process yields a total of 47104 16-bit words of data, the collection of which defines a 6 second instrument cycle. In parallel, the direct TOF events are accumulated into a TOF spectrum with 256 channels, which are to be reported less frequently, but at least every 3.2 minutes (direct event accumulation period is to be under software control). The TOF spectrum will make evident the presence of minor ion species, which will provide verification and updating of the mass calibration, and, in combination with the singles rates and other monitors, will serve as a general diagnostic database.

In view of the TIDE data rate allocation of 4kbps (3000 bytes/spin), methods must be implemented to reduce the volume of data to fit the telemetry allocation. The methods include collapse of the array (to eliminate oversampling or to deliberately reduce the sampling density), two forms of data compression, and, optionally, the truncation of the data based on a priority scheme.

The TIDE instrument sweeps the RPA potential ( $V_{RPA}$ ) and the Mirror potential ( $V_{mirror}$ ), the latter being specified and controlled as a fraction of the former. TIDE's response energy and aperture are controlled by these potentials. The potentials are, by default, specified by tables stored in ROM and

may be altered in flight by uploading alternate tables into RAM. In addition, automatic sensitivity control is provided to optimize counting statistics and to extend TIDE's dynamic range. The lower sensitivity settings result in narrower azimuth angle response as well as narrower energy response. Moreover, in order to protect the MCPs from damaging excitation rates, the rates are continuously monitored, and evasive action is taken in response to potentially damaging conditions.

In order to provide for enhanced azimuth angle sampling commensurate with the narrow angular response of TIDE's "stopped down" aperture, a High Angular Resolution Option is provided. Unlike the normal Science Mode in which data collection for each spin begins at the sun pulse, the start of data collection will change over several spins. This option will allow data to be collected corresponding to 32 step energy sweeps that begin at the sun pulse, shifted a quarter sweep from the sun pulse, shifted a half sweep from the sun pulse, and shifted three quarters sweep from the sun pulse.

A High Time Resolution Option will be available in order to provide enhanced temporal resolution of single spins of data. When this option is selected, the level of array collapse is maximized, and only the (prioritized) data which can be sent in a single spin are telemetered. This mode may be triggered at any time by uplink command, or it may be triggered by a programmed combination of signals derived from the Hydra and EFI instruments and from the time history of TIDE data, as indicated by a moment variability index.

In addition, there are collapse options, complete or truncated reporting, dead time correction, data prioritization schemes, and data compression which may be selected in various combinations.

## 2 INSTRUMENT CONTROL

Instrument control includes initializing and updating the instrument hardware.

### 2.1 DPU Turn-On Sequence.

The Instrument Mode Processor (IMP) and the Data Processor (DP) shall verify proper hardware operation and initialize the system to a known default state.

#### 2.1.1 RAM Tests

RAM tests shall be performed with instructions executed out of ROM. The IMP shall perform a test on IMP RAM, direct event acquisition memory, and shared memory. (Shared memory is the memory accessible to both the IMP and the DP.) The DP shall test the Bulk RAM, TOF acquisition memory, and shared memory. The RAM tests will ensure that bits in RAM can be set and cleared. The success or failure status of the RAM test shall be revealed in the housekeeping telemetry data. Status bits for each processor shall be telemetered in housekeeping to indicate the status of the test. When an error has occurred, the relevant processor shall write the details of the error to memory and continue normal processing.

### 2.1.2 PROM Check

The IMP and DP shall each calculate a checksum over their respective PROM space. These checksums shall be compared to pre-flight generated checksums, which are burned into the PROMs. A status bit for each processor shall be telemetered in housekeeping to indicate the result of checksum comparison.

### 2.1.3 Software Download

The IMP and DP shall copy software code and initialized data from their respective PROM to their respective RAM space. Areas of RAM are reserved for a stack and other nonstatic data. The normal processing state shall be to execute flight code from RAM.

### 2.1.4 HV and MCP Power Supply Initialization

The power supply hardware registers shall be initialized to zero.

### 2.1.5 Accumulation Period Initialization

At power-up the accumulation period shall be initialized to 5.86 ms to correspond to a nominal spacecraft spin of 6 seconds.

### 2.1.6 Phase Shift Initialization

The phase shift register shall be initialized to zero phase shift.

### 2.1.7 Watchdog Function

Watchdog function is disabled at power-on.

### 2.1.8 Energy Sweep Table Initialization

The energy sweep table is initialized with values from the first of the five energy sweep tables stored in ROM. The contents of the ROM sweep tables are listed in Appendix A.

### 2.1.9 Mass Look-Up Table Initialization

The mass look-up table is initialized by expanding the first five of the eight mass look-up table entry specifications stored in ROM. (See section 2.5.)

## 2.2 Spacecraft Spin Synchronization (Accumulation Period Adjustment)

The spacecraft spins at 10 rpm, nominally. The DPU hardware has the ability to synchronize to the spacecraft sun pulse. By default, the DPU software shall dynamically adjust its data collection to correspond to the changing spacecraft spin period and to ensure that the instrument will accumulate data for exactly 32 energy steps for each of exactly 32 energy sweeps. This adjustment shall be made for spins of 10rpm +/- 7.5%. An additional option of the DPU is to ignore synchronization to the spacecraft sun pulse and operate on an internal 6 second time base. This option shall be commandable.

## 2.3 Data Acquisition Phase Shift

The acquisition spin cycle typically begins when the sun pulse signal is received. The ability to start data collection between 0 and 22.5 degrees offset from the sun pulse is required. This phase shift will be specified by an uplink command. See section 3.2.7.2 for the phase shift requirement for the High Angular Resolution Sub-mode.

## 2.4 Power Supply Control

The HV and two MCP supplies may be disabled, enabled, and commanded to certain voltages via uplink command.

The RPA and mirror/RPA supplies shall be updated 1024 times per spin to cause the instrument to perform 32 sweeps of 32 energy steps each spin. The energies shall be swept from high to low values. The thirty-second step of each sweep is used to charge-up from the lowest to the highest energy step. The values to be written to the RPA and mirror/RPA supplies are specified by one of the five onboard ROM Energy Sweep Tables (defined in Appendix A) or by one of the two RAM Energy Sweep Tables, whose contents must be uploaded. The desired table must be selected via command. If Automatic Sensitivity Control is enabled, the active mirror/RPA values may be dynamically changed on board, in response to overcounting or undercounting by the instrument. Default Auto Sensitivity Control (section 2.4.1) is enabled by default. It may be disabled by a hazardous command or enhanced by choosing Optional Auto Sensitivity Control (section 2.4.2).

### 2.4.1 Default Automatic Sensitivity Control

Default Automatic Sensitivity Control is used to avoid excessively high counting from the microchannel plates. It shall be in effect by default but may be disabled via hazardous command. When overcounting is detected,  $V_{\text{mirror/RPA}}$  values are decreased. The required algorithm to be performed on board is described in Appendix B.

### 2.4.2 Optional Automatic Sensitivity Control

At power-on, Optional Automatic Sensitivity Control shall be disabled. It may be enabled via uplink command to ensure statistically meaningful data. It can be enabled only if all power supplies are on. Optional Auto Sensitivity Control involves increasing  $V_{\text{mirror/RPA}}$  values when undercounting is detected and decreasing  $V_{\text{mirror/RPA}}$  values when overcounting is detected. The

required algorithm to be performed on board is described in Appendix B.

## 2.5 Mass Selection

Data is binned onboard according to a mass look-up table, which defines up to five masses. A mass description consists of a range of TOF values (0 - 255), which correspond to the desired mass. Five mass descriptors shall be specified and expanded into the Mass Look-Up Table upon uplink command. There shall be space in onboard RAM for 8 mass descriptors, which are specified by upload. Also there shall be 8 mass descriptors stored in ROM. The ROM descriptors are shown in Appendix C.

## 2.6 DPU Debug Mode

A debug mode of operation is required. It will be invoked by a bootstrap discreet command. This mode will accommodate code patching and memory dumps. Diagnostic and debug information shall be telemetered. No science data telemetry is required when the instrument is in this mode.

Patches shall be accommodated via direct data loads into specified memory addresses. To patch code, a data load, containing the new code, is sent to a patch area address. The maximum size of one upload is 2047 bytes. The flight software that handles patches shall verify that a checksum performed on the uploaded data matches an uploaded checksum before actually loading the patch code into the specified address area. If the uploaded code is longer or shorter than the code to be replaced, a second upload may be necessary to write a jump instruction over some of the old code so that proper flow from old to new back to old code is achieved.

## 2.7 Plasma Source Instrument (PSI) Interface

The TIDE DPU will provide the PSI with an interface to the telemetry and command streams. PSI commands shall be passed through the TIDE DPU to the PSI. (The PSI commands are listed in Appendix D.) TIDE DPU shall also read status information and monitor values from the PSI and shall report these values in housekeeping bytes of the telemetry stream.

# 3 DATA PROCESSING

Data processing during any given spin is defined by one of two major modes: Dump Mode or Science Mode. Additionally, Science Mode has numerous options or submodes associated with it. Modes and options may be selected by uplink commands. Any changes to data processing modes or options shall take place only on superspin boundaries, with the exception of the initiation of the High Time Resolution Sub-mode. (A superspin is defined to be 32 spins and is fixed.) The mode shall be telemetered in housekeeping data. In addition, a mode change pending flag shall be telemetered to indicate a mode change is in progress. This setting of this flag shall be reflected beginning in the first housekeeping frame that follows the receipt of an Execute Stored Superspin Commands command by the flight software. The flag shall remain set until the housekeeping frame following the end of the set-up superspin. (The set-up superspin is the superspin that immediately precedes the superspin in which a new mode is initiated.)

### 3.1 Dump Mode

Dump Mode will allow the contents of onboard PROM or RAM to be telemetered. Generally, memory contents shall be dumped beginning at the commanded start address (from either IMP or DP memory space) and shall continue for one superspin. For the special case of a mass look-up table dump, specifying any address in the range 80000-8ffff (hex) shall initiate a dump of the inactive and active Mass Look-up Tables.

### 3.2 Science Mode

In the Science Mode, mass data is optionally dead time corrected, collapsed, compressed, prioritized, and telemetered in various ways. Start singles may be treated as a "sixth mass" and collapsed and telemetered analogously to the five masses. Pseudo-moments shall be calculated for each of the five masses, if execution time permits.

#### 3.2.1 Dead Time Correction

TIDE data must be corrected to account for the dead time after an ion is processed in which no other ion can be detected. Correction to M/q data and start singles must be performed on board. This data is collapsed on board, and correction must be performed before the data is collapsed. There is no requirement for on-board correction of the direct events. The required dead time correction algorithm is shown in Appendix E.

#### 3.2.2 Collapse Options

Collapses are sums of various energy and azimuthal angle bins. If a sum becomes too large to fit in a 16 bit accumulation buffer, the buffer will not roll over, but will contain the maximum value (65535), which can be stored in a 16-bit location. When in the Science Mode, data shall be collapsed as commanded in one of the following ways.

##### 3.2.2.1 No Collapse (collapse option 0)

##### 3.2.2.2 Energy Collapse (collapse option 1)

Combine data from every two adjacent energies by summing counts, yielding a collapse factor of 2.0.

##### 3.2.2.3 Medium Angular Resolution Collapse (collapse option 2) (See Figure 1.)

Combine groups of azimuth bins so as to form combined bins of equal range as follows, yielding a collapse factor of 1.9:

- Channels 4, 5: no collapse.
- Channels 3, 6: combine alternate azimuthal bins.
- Channels 2, 7: combine every 4 adjacent azimuthal bins.
- Channel 1 : combine every 8 adjacent azimuthal bins.

**3.2.2.4      Low Angular Resolution Collapse (collapse option 3)**  
(See Figure 2.)

Combine groups of azimuth bins so as to form combined bins of equal range as follows, yielding a collapse factor of 3.9:

- Channels 4, 5: combine alternate azimuthal bins.
- Channels 3, 6: combine every 4 adjacent azimuthal bins.
- Channels 2, 7: combine every 8 adjacent azimuthal bins.
- Channel 1 : combine every 16 adjacent azimuthal bins.

**3.2.2.5      Energy/Medium Angular Resolution Collapse (collapse option 4)**

Combine the Energy Collapse (collapse option 1) and the Medium Angular Resolution Collapse (collapse option 2) for a total collapse factor of 3.8.

### MEDIUM ANGULAR RESOLUTION COLLAPSE

	A0	A4		A31
D4				
D5				
D3				
D6	A0-A1			
D2				
D7	A0 - A3			
D1	A0 - A7			

Figure 1.

### LOW ANGULAR RESOLUTION COLLAPSE

	A0	A4		A31
D4				
D5	A0-A1			
D3				
D6	A0 - A3			
D2				
D7	A0 - A7			
D1	A0 - A15			

A = azimuthal angle

D = detector channel

Figure 2.

### 3.2.2.6 Energy/Low Angular Resolution Collapse (collapse option 5)

Combine the Energy Collapse (collapse option 1) and the Low Angular Resolution Collapse (collapse option 3), yielding a collapse factor of 7.8.

### 3.2.2.7 Calibration Supercollapse (collapse option 6)

The data from the last 16 azimuthal angles of each spin is collapsed into one azimuthal bin. When this collapse is selected, a special set of data is telemetered, which differs from the normal science set of mass data. Each spin, all 5 masses (5 masses x 7 detector channels x 32 energies x 1 azimuth angle) shall be reported, along with all 11 scalar data entities (11 scalars x 32 energies x 1 azimuth angle). The mass and scalar data is compressed with a lossy method to reduce each value from a 16-bit to an 8-bit number. (See section 3.2.5.)

## 3.2.3 Priority Ordering

The priority ordering of data to be telemetered shall be commandable. One of the two prioritization schemes for detector channels, shown in Figures 3 and 4, may be selected by command. Additionally the ordering of the masses in the telemetry stream can be commanded. There is no requirement for the ordering of the energies and angles.

## 3.2.4 Reporting Option

### 3.2.4.1 Truncated Reporting

This option produces maximum time resolution data, with the potential for loss of completeness of the distribution. For each spin of data collected, data in the amount that will fit into one spin allocation ( $\sim 4608*6/9.2 = \sim 3005$  bytes) of telemetry space shall be reported. The rest of the data is truncated.

### 3.2.4.2 Complete Reporting

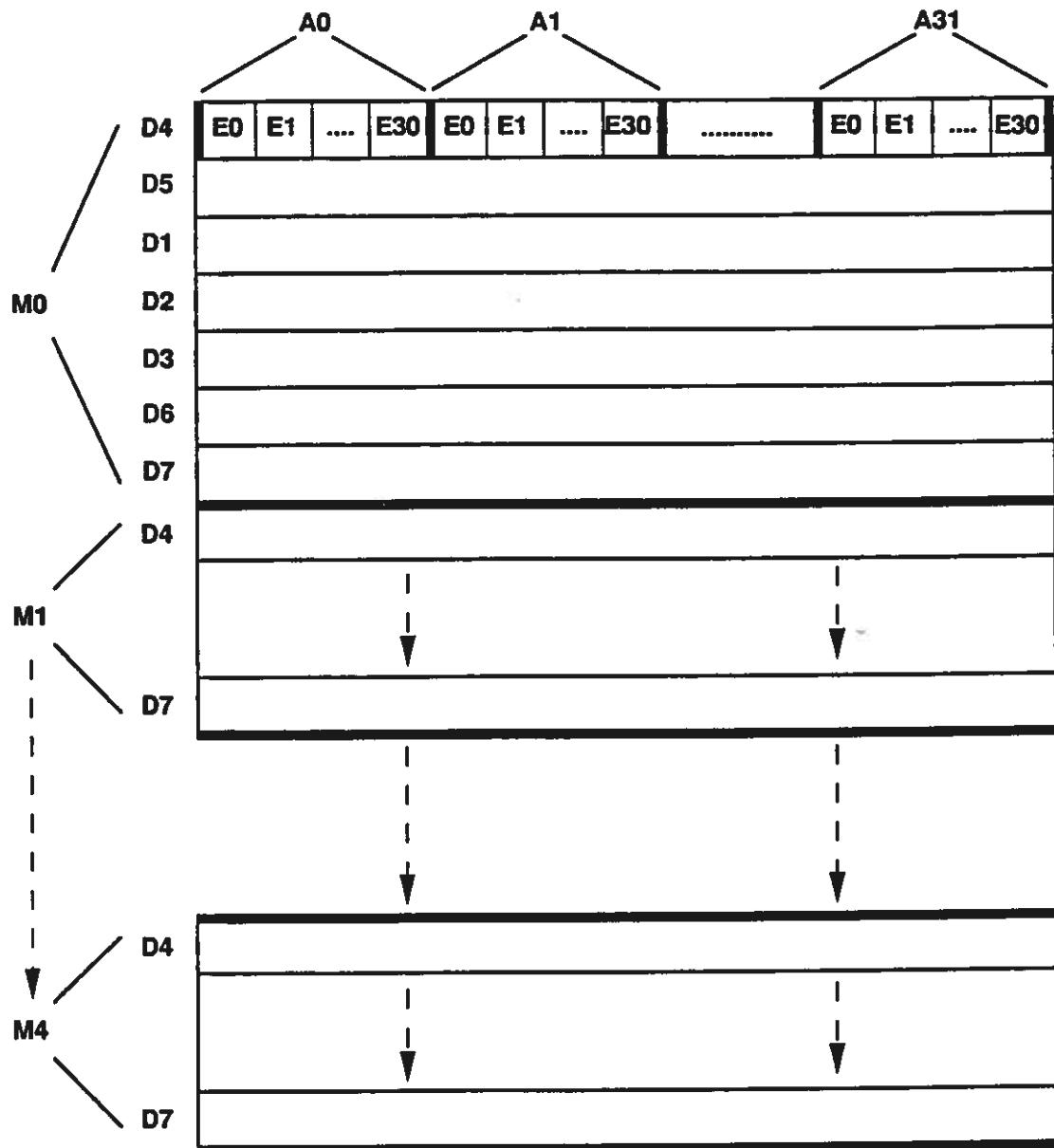
This option provides snapshots of data, with the potential for loss of time resolution. A distribution of data is reported in as many spin allocations of telemetry space as are required to completely report the distribution. The newest spin of data accumulated is then reported, the intervening spins having been lost. The ability to select snapshots of a subset of the masses is required. Also, there shall be an option to force two major ions plus one minor ion to comprise each snapshot. The two major ions shall be reported each snapshot, but the minor ions shall be rotated.

## 3.2.5 Lossy Compression

Any M/q or singles data which is reported shall be collapsed with a lossy compression method to reduce 16-bit words to 8 bits. The mapping of the raw 16-bit counts to the 8 bit representation is shown in Appendix F. The error produced by this mapping is less than 3 percent.

**PRIORITY ORDERING  
SCHEME 0**

3348-FSRD-01  
Rev. 1 Chg. 0  
Page 14



**E = energy**

**D = detector channel**

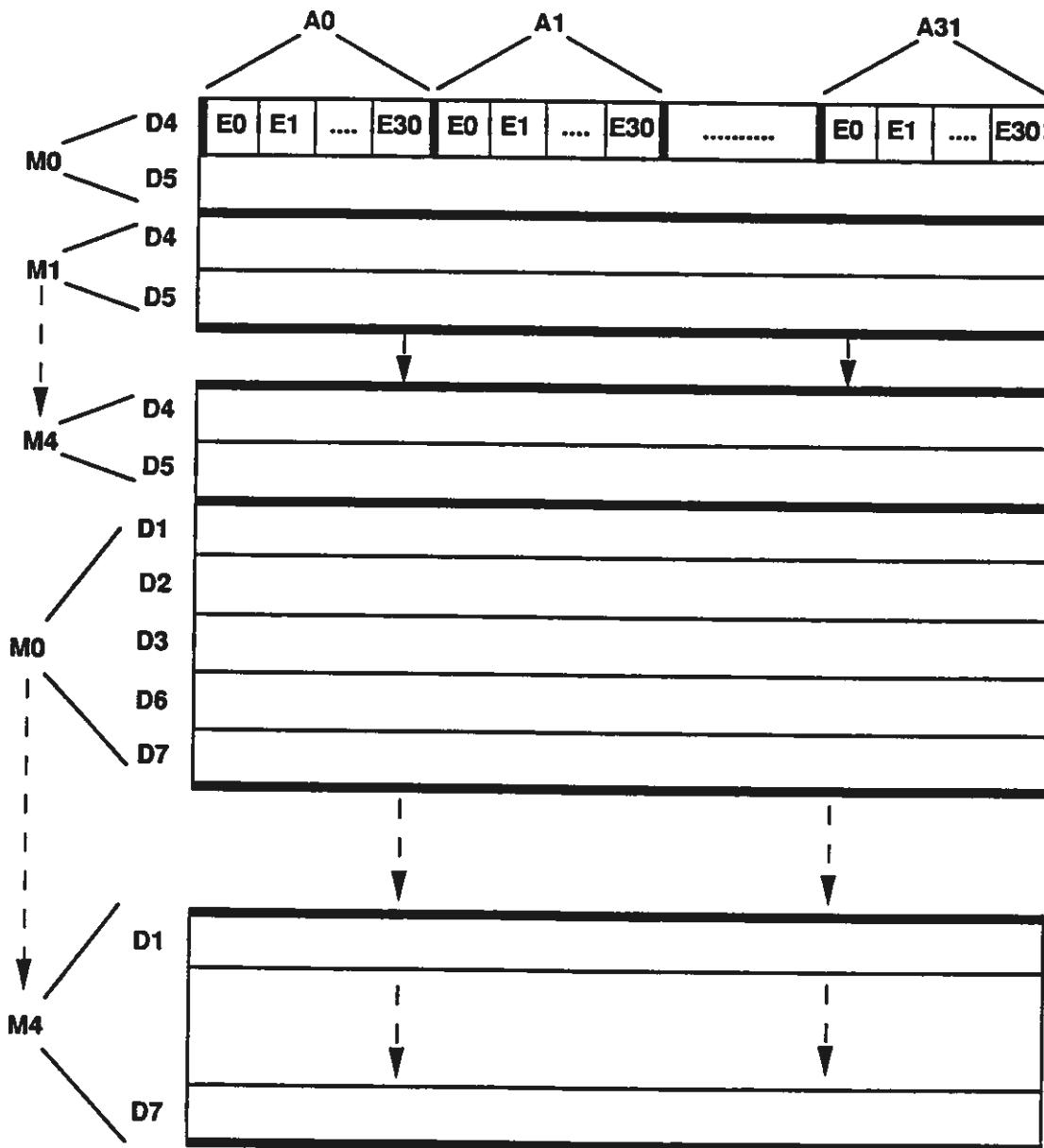
**A = azimuthal angle**

**M = Mass**

Figure 3.

**PRIORITY ORDERING  
SCHEME 1**

3348-FSRD-01  
Rev. 1 Chg. 0  
Page 15



**E = energy**

**D = detector channel**

**A = azimuthal angle**

**M = Mass**

Figure 4.

### 3.2.6 Rice Compression

A lossless compression technique to be performed on the science data may be selected by uplink command. This compression algorithm uses techniques described in Some Practical Universal Noiseless Coding Techniques, JPL Publication 79-22, Robert F. Rice. The enabling of Rice Compression via command shall have no affect if the instrument is in Dump or Calibration Super Collapse mode.

### 3.2.7 Sub-modes

A few combinations of the collapse options, priority ordering, and reporting options predefine special sub-modes for processing data.

#### 3.2.7.1 Default Science Sub-mode

The instrument shall default to this mode at turn-on. Data shall be collapsed with the Energy/Low Angular Resolution Collapse (collapse option 5). Priority Scheme 0 is used, with the "singles mass" ("sixth mass") being of highest priority, followed by masses 0, 1, 2, 3, and 4. Truncated Reporting and lossy compression are enabled.

#### 3.2.7.2 High Angular Resolution Sub-mode

This mode is defined in order to obtain higher angular resolution of the instrument than is obtained with the normal data accumulation spin cycles. Time resolution is traded for higher angular resolution by accumulating data beginning at phase shifts of  $0^\circ$ ,  $2.81^\circ$ ,  $5.63^\circ$ , and  $8.44^\circ$ . The instrument will collect data beginning at each of these phase shifts for a commandable number of spins before proceeding to the next phase shift. The data acquired is collapsed with the Medium Angular Resolution Collapse (collapse option 2) and truncated or complete reporting may be chosen. The mode is enabled or disabled with an uplink command.

#### 3.2.7.3 High Time Resolution Sub-mode

This mode shall use the Energy/Low Angular Resolution Collapse (collapse option 5) and truncated reporting. The priority ordering is commandable. This mode may be enabled by direct uplink command or it may be triggered by a selectable combination of triggering signals. The possible triggers are EFI burst signal, Hydra burst signal, and a TIDE trigger which is a flag generated by the moments calculation routine (section 3.2.9). The selection of which valid triggers are needed to enable the High Time Resolution Sub-mode will be made by uplink command. An EFI trigger occurs when the EFI signal transitions from high to low. A Hydra trigger occurs when the Hydra signal transitions from low to high.

Unlike other mode changes which occur at superspin boundaries, the switch to High Time Resolution Sub-mode is made at the next spin boundary, after receiving valid trigger(s). The instrument shall then remain in this mode for n complete superspins, where n is defined by uplink command. The maximum value of n is 15. The instrument shall then revert to processing with the options that were enabled prior to entering the High Time Resolution Sub-mode.

If another valid trigger is received while still in the High Time Resolution Mode, the dwell period shall become the longest of two values. It shall be either the new dwell or the remaining period left of the original dwell.

### 3.2.8 Scalar Data Efficiency Calculations

Scalar data is used to check the relative efficiency of TIDE detectors. Not all scalar data can be transmitted; this would require 11 scalar entities x 32 energies x 32 angles = 11,264 values per spin. Therefore, on-board processing will be used to measure relative efficiency over one spin period. Efficiency is expected to change on much longer time scales, if at all. Efficiency calculations shall be done for stops, start converts, time-outs, and resets. (Efficiency information for each of the start singles may be obtained from the moment results.)

### 3.2.9 Moment Calculations

For each spin of data, a set of moments over detector sectors 2-7 shall be computed, to the extent permitted by available execution time. The reported moments shall include, for up to five reported species, the centroid and the boxcar width of the azimuth and polar angle distributions in units of bins, as well as the centroid, boxcar height, and boxcar width of the energy distribution for each reported ion. A rolling record of these moments over the preceding four spins shall be maintained by the moments routine. A variability flag shall be generated at the completion of each spin for which the computed standard deviation of the history record, for any of the moments applying to the primary mass, exceeds an uploadable value.

#### 3.2.9.1 Polar Angle Centroid and Width

The raw data is collapsed into a 6 element array (channel 1 is ignored) by summing over energy and azimuth. The centroid and width, in data bin number with 16 bit accuracy, are calculated. The formula is given in Appendix G.

#### 3.2.9.2 Azimuth Angle Centroid and Width

The raw data is collapsed into a 32 element array by summing over energy and polar sector. Prior to the calculation of the centroid the array is surveyed to determine the quadrant in which the centroid is most probable. This allows the array to be shifted to increase the likelihood that the bulk of the distribution lies in the center of the array. The centroid and width, in data bin number with 16 bit accuracy, are calculated by the formula given in Appendix G.

#### 3.2.9.3 Energy Centroid and Width

The raw data is collapsed in a 32 element array by summing over polar sector and azimuth. Next the data are corrected for sensitivity variations due to differing Mirror/RPA ratios. By using the commanded RPA voltage step and the Mirror/RPA correction for the center of the energy bandpass, the calculation shall result in an "average" energy and a width in energy units. The centroid and width are calculated by the formula given in Appendix G.

4 COMMANDING

#### 4.1 Pulse Commands

The pulse commands which communicate with the instrument via dedicated lines are as follows:

- 1) IMP Reset
  - 2) Bootstrap 1
  - 3) Bootstrap 2
  - 4) HV Arm
  - 5) HV Master Off

Bootstrap 1 causes the instrument to boot up using an alternate ROM in case the normal start-up ROM becomes corrupted. Bootstrap 2 sets a register flag. When the flight software sees this flag set at power on, it shall go into debug mode (section 2.6).

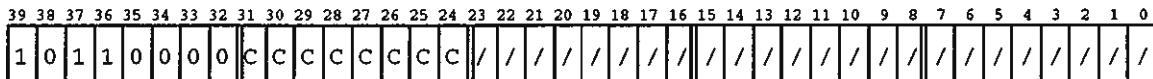
## 4.2 Serial Data Command Formats

Serial data commands will be supplied to the instrument in a 40-bit serial word. The leading 8 bits of the word form an address/opcode which describes the type of command being sent. The first 6 bits are the TIDE address 101100. The next 2 bits are the command mode bits defined by GE document 3282065, GGS General Instrument Interface Specification, as follows:

- 00 Major Mode
  - 01 Minor Mode
  - 10 Start of Data Block Transfer
  - 11 Data Block

The remaining 32 bits will contain an instrument opcode, parameters, and data, as shown in the figures below.

## Major Mode



Minor Mode

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	C	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D			

Start of Data Block Transfer

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	P	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	W	W	W	W	W	W	W	W	W	W

Data Block

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	1	1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D			

CCCCCCCC = Instrument Command Opcode

//////// = Unused

DDDDDDDD = Data

P = Processor (0 - IMP, 1 - DP)

AAAAAAAAAAAAAA = Start Address of Block Transfer

WWWWWWWWWW which = Number of Command Words following the Start of Block Transfer  
 are part of the upload (includes Block Header and Block Checksum)

All required Major and Minor Serial Command formats are defined in Appendix H.

When transmitting a direct data load, the load shall specify the actual on-board address into which the data will be loaded. When uploading standard operating data tables, a table number shall be specified, rather than an address into which the data should be loaded. Specifying a table number protects onboard code and data from being accidentally overwritten by an upload command with an absolute address. When sending a direct data load, the data load address is specified in the Start of Data Block Transfer record illustrated above. For other uploads, the table number is specified in the Data Block record following the Start of Data Block Transfer record. The format of this first Data Block record is:

Data Block Header

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	1	1	T	T	T	T	T	T	T	T	/	/	/	/	/	/	/	/	/	/	/	L	L	L	L	L	L	L	L	L	L			

//////// = Unused

LLLLLLLLLL = Length of the actual data to be loaded (in bytes)

TTTTTTTT = Table Identification Number

IMP Table ID Numbers

00 - Absolute data load (only load that uses address field in Start of Data Block Transfer record)  
01 - Cal format ESWEEP table 0  
02 - Cal format ESWEEP table 1  
03 - Spare  
04 - Mass look-up Table (MLUT)  
05 - Cal pulser sequence table  
06 - Auto Sensitivity ESWEEP table 0  
07 - Auto Sensitivity ESWEEP table 1  
08 - Cal pulser sequence table (A)  
09 - Cal pulser sequence table (B)

DP Table ID Numbers

80 - Absolute data load  
81 - Auto sensitivity thresholds

The last Data Block record of an upload also has a special format. It contains a checksum associated with the upload. The checksum is calculated by summing all doubleword (32-bit) commands in the data load, including the Start of Data Block Transfer Command and the Data Block Header record.

The format of this checksum record is:

Data Block Checksum

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	1	1	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		

SSSS.... = the checksum

## 5 TELEMETRY

TIDE has been allocated 46 bytes of housekeeping data space and 4,608 bytes of science data space per major frame. (See IS 3282162 GGS ICD for TIDE Instrument.) These bytes are interspersed in the complete POLAR Laboratory Major Telemetry Frame, with TIDE data bytes occurring only singly or in groups of 2 or 3. The TIDE telemetry software shall obtain the proper number of bytes (1, 2, or 3), from the TIDE data, to transmit each time a telemetry request comes from the spacecraft.

### 5.1 Housekeeping Data

The allocation for housekeeping data is 45 bytes. Housekeeping data is major frame synchronous; that is, it shall be reported once each major frame. The required items to be reported in housekeeping are listed in Appendix I.

## 5.2 Science Data

Science data shall be telemetered in structures called spin packets. The spin packets are not synchronous with the telemetry frame, rather they may begin and end anywhere in a major frame of data. The spin packets shall be approximately spin synchronous. The spin packet format is shown in Appendix J. Each spin packet consists of a header, followed by a varying number of data products.

### 5.2.1 Spin Header

Each spin packet contains a spin header consisting of the following items:

#### 5.2.1.1 Sync Word

The sync word shall appear in the telemetry stream as EB90<sub>16</sub>. It marks the beginning of a spin packet.

#### 5.2.1.2 Spin Packet Length

The total length, in bytes, of the spin packet shall be in a word in the spin packet header. The low byte of the length is telemetered first.

#### 5.2.1.3 Mode ID

The mode ID indicates the mode that each processor was operating in relative to the data in this spin packet. This is the same parameter as the System Status 3 housekeeping byte listed in Appendix I.

#### 5.2.1.4 Spin Counter

This counter counts from 0 to 255 and rolls over. It is incremented by one each spin.

#### 5.2.1.5 Time Tag

This time tag is associated with the items in the spin packet header. It marks the end of the acquisition spin of corresponding data. The time tag shall consist of a major frame counter, a minor frame counter, and a telemetry word counter. The same major frame counter is originally inserted in the housekeeping data. It is inserted in the major frame in which the sun pulse occurred which began the acquisition of the data, relevant to the current spin packet header. Because a Universal Time is also stored by the spacecraft in each major frame, the time of data collection can be related to a real time.

#### 5.2.1.6 Continue Number

This number is relevant when the instrument is in Complete Reporting Mode (section 3.2.4.2). It shall number, from 0 to n, the spin packets which contain data collected from the same spin.

#### 5.2.1.7 MAGAZ

This word will contain an indication of the spacecraft MAGAZ as read from the DPU hardware.

#### 5.2.1.8 MAGEL

This byte will contain an indication of the spacecraft MAGEL as read from the DPU hardware.

#### 5.2.1.9 Accumulation Period

This will indicate the length of the accumulation period during the spin.

#### 5.2.1.10 TOF Efficiency Numbers

Four bytes in the spin header shall be reserved for the four efficiency numbers (one each for start converts, stops, time-outs, and resets). Each 16-bit efficiency number shall be lossy compressed. (See section 3.2.8.)

#### 5.2.1.11 Moments

There shall be 36 bytes reserved for the lossy compressed moments results.

#### 5.2.1.12 Invalid Events

This value is the lossy compressed sum of all invalid events (channel zero events) that occurred during the spin.

#### 5.2.1.13 Trickled Direct Events

Direct Events are accumulated over a superspin (32 spins) and shall be trickled down in the spin headers of the subsequent superspin. Each direct event value is 4 bytes long. During even superspins, the direct event data accumulated in even numbered TOF bins shall be trickled. During odd superspins, the odd numbered TOF bin information is telemetered.

#### 5.2.1.14 Commands Received Counter

The total number of commands received during the current spin shall be reported.

#### 5.2.1.15 Data Product Counter

The number of data product packets in the spin packet is contained in this byte.

#### 5.2.1.16 Spin Header Checksum

A checksum over the spin packet header is calculated and reported.

### 5.2.2 Data Product Packets

The science data shall be reported in data product packets. Each packet shall contain a sync byte, data product id, packet length, time tag (major frame counter, minor frame counter, spin counter), and checksum, along with the associated science data. This most significant bit of the packet length is a Rice Compression status bit indicating whether that data product has been compressed (0 = no compression, 1 - compression). Listed below are special types of data products which are required.

#### 5.2.2.1 Instrument Parameters Data Product

The first data product packet that will follow the spin header which corresponds to a superspin boundary shall be the Instrument Parameters data product. It shall contain the information listed in Appendix K.

#### 5.2.2.2 Instrument Parameter Changes Data Product

For spins other than the spin beginning a superspin, if there has been a change to a subset of the items listed, an Instrument Parameters Change Data Product should be telemetered as the first data product in the spin packet. The format of this data product is given in Appendix K.

#### 5.2.2.3 Direct Events Sector 0 Data Product

By default, once per superspin the Direct Events Sector 0 data product is generated and telemetered as the second data product of the superspin. The telemetry of this data product may be disabled or re-enabled via uplink command.

#### 5.2.2.4 Dump Data Product

Each dump data product shall have as its data a four byte memory start address of data being dumped in the packet followed by 1024 bytes of memory contents.

## A P P E N D I X    A

### ROM ENERGY SWEEP TABLE 0

The  $V_{RPA}$  and  $V_{mirror}/V_{RPA}$  sweep is defined by two tables, the  $V_{RPA}$  - sensitivity level table and the sensitivity level -  $V_{mirror}/V_{RPA}$  table. The ROM tables are:

$V_{RPA}$  - SENSITIVITY LEVEL TABLE  
 TABLE

Energy Step	12-bit $V_{RPA}$	Desired $V_{RPA}$	Sensitivity Level	Sensitivity Level	8-bit $V_{mirror}/V_{RPA}$	Actual
	$V_{mirror}/V_{RPA}$					
0	4095	300.00	11	0	0	0.0000
1	3253	238.32	11	1	76	0.2980
2	2584	189.30	11	2	86	0.3373
3	2052	150.33	11	3	87	0.3412
4	1630	119.41	11	4	89	0.3490
5	1295	94.87	11	5	91	0.3569
6	1029	75.38	11	6	95	0.3725
7	817	59.85	11	7	99	0.3882
8	649	47.55	11	8	105	0.4118
9	516	37.80	11	9	113	0.4431
10	410	30.04	11	10	123	0.4824
11	325	23.81	11	11	137	0.5373
12	258	18.90	11	12	155	0.6078
13	205	15.02	11	13	179	0.7020
14	163	11.94	11	14	212	0.8314
15	129	9.45	11	15	255	1.0000
16	103	7.55	11			
17	82	6.01	11			
18	65	4.76	11			
19	52	3.81	11			
20	41	3.00	11			
21	33	2.42	11			
22	26	1.90	11			
23	21	1.54	11			
24	16	1.17	11			
25	13	0.95	11			
26	10	0.73	11			
27	8	0.59	11			
28	6	0.44	11			
29	5	0.37	11			
30	4	0.29	11			
31	4095	300.00	11			

ROM ENERGY SWEEP TABLE 1

$V_{RPA}$  - SENSITIVITY LEVEL TABLE  
 TABLE

Energy Step	12-bit $V_{RPA}$	Desired $V_{RPA}$	Sensitivity Level
0	683	50.04	7
1	575	42.12	7
2	485	35.53	7
3	409	29.96	7
4	345	25.27	7
5	291	21.32	7
6	245	17.95	7
7	207	15.16	7
8	174	12.75	7
9	147	10.77	7
10	124	9.08	7
11	105	7.69	7
12	88	6.45	7
13	74	5.42	7
14	63	4.62	7
15	53	3.88	7
16	45	3.30	7
17	38	2.78	7
18	32	2.34	7
19	27	1.98	7
20	23	1.68	7
21	19	1.39	7
22	16	1.17	7
23	14	1.03	7
24	11	0.81	7
25	10	0.73	7
26	8	0.59	7
27	7	0.51	7
28	6	0.44	7
29	5	0.37	7
30	4	0.29	7
31	683	50.04	7

SENSITIVITY LEVEL -  $V_{mirror}/V_{RPA}$

Sensitivity Level	8-bit $V_{mirror}/V_{RPA}$	Actual
0	0	0.0000
1	76	0.2980
2	86	0.3373
3	87	0.3412
4	89	0.3490
5	91	0.3569
6	95	0.3725
7	99	0.3882
8	105	0.4118
9	113	0.4431
10	123	0.4824
11	137	0.5373
12	155	0.6078
13	179	0.7020
14	212	0.8314
15	255	1.0000

ROM ENERGY SWEEP TABLE 2

$V_{RPA}$  - SENSITIVITY LEVEL TABLE  
 TABLE

Energy Step	12-bit $V_{RPA}$	Desired $V_{RPA}$	Sensitivity Level
0	4095	300.00	11
1	3835	280.95	11
2	3584	262.56	11
3	3341	244.76	11
4	3106	227.55	11
5	2881	211.06	11
6	2663	195.09	11
7	2454	179.78	11
8	2254	165.13	11
9	2062	151.06	11
10	1879	137.66	11
11	1704	124.84	11
12	1538	112.67	11
13	1381	101.17	11
14	1231	90.18	11
15	1091	79.93	11
16	959	70.26	11
17	835	61.17	11
18	720	52.75	11
19	614	44.98	11
20	516	37.80	11
21	426	31.21	11
22	345	25.27	11
23	273	20.00	11
24	209	15.31	11
25	153	11.21	11
26	107	7.84	11
27	68	4.98	11
28	38	2.78	11
29	17	1.25	11
30	4	0.29	11
31	4095	300.00	11

SENSITIVITY LEVEL -  $V_{mirror}/V_{RPA}$

Sensitivity Level	8-bit $V_{mirror}/V_{RPA}$	Actual
0	0	0.0000
1	76	0.2980
2	86	0.3373
3	87	0.3412
4	89	0.3490
5	91	0.3569
6	95	0.3725
7	99	0.3882
8	105	0.4118
9	113	0.4431
10	123	0.4824
11	137	0.5373
12	155	0.6078
13	179	0.7020
14	212	0.8314
15	255	1.0000

ROM ENERGY SWEEP TABLE 3

$V_{RPA}$  - SENSITIVITY LEVEL TABLE  
 TABLE

Energy Step	12-bit $V_{RPA}$	Desired $V_{RPA}$	Sensitivity Level
0	683	50.04	7
1	639	46.81	7
2	597	43.74	7
3	557	40.81	7
4	518	37.95	7
5	480	35.16	7
6	444	32.53	7
7	409	29.96	7
8	376	27.55	7
9	344	25.20	7
10	313	22.93	7
11	284	20.81	7
12	256	18.75	7
13	230	16.85	7
14	205	15.02	7
15	182	13.33	7
16	160	11.72	7
17	139	10.18	7
18	120	8.79	7
19	102	7.47	7
20	86	6.30	7
21	71	5.20	7
22	58	4.25	7
23	45	3.30	7
24	35	2.56	7
25	26	1.90	7
26	18	1.32	7
27	11	0.81	7
28	6	0.44	7
29	3	0.22	7
30	1	0.07	7
31	683	50.05	7

SENSITIVITY LEVEL -  $V_{mirror}/V_{RPA}$

Sensitivity Level	8-bit $V_{mirror}/V_{RPA}$	Actual
-------------------	----------------------------	--------

0	0	0.0000
1	76	0.2980
2	86	0.3373
3	87	0.3412
4	89	0.3490
5	91	0.3569
6	95	0.3725
7	99	0.3882
8	105	0.4118
9	113	0.4431
10	123	0.4824
11	137	0.5373
12	155	0.6078
13	179	0.7020
14	212	0.8314
15	255	1.0000

ROM ENERGY SWEEP TABLE 4

$V_{RPA}$  - SENSITIVITY LEVEL TABLE  
 TABLE

Energy Step	12-bit $V_{RPA}$	Desired $V_{RPA}$	Sensitivity Level
0	137	10.04	3
1	128	9.38	3
2	120	8.79	3
3	113	8.28	3
4	105	7.69	3
5	98	7.18	3
6	91	6.67	3
7	85	6.23	3
8	78	5.71	3
9	72	5.27	3
10	66	4.84	3
11	61	4.47	3
12	55	4.03	3
13	50	3.66	3
14	45	3.30	3
15	41	3.00	3
16	36	2.64	3
17	32	2.34	3
18	28	2.05	3
19	25	1.83	3
20	21	1.54	3
21	18	1.32	3
22	15	1.10	3
23	13	0.95	3
24	10	0.73	3
25	8	0.59	3
26	6	0.44	3
27	5	0.37	3
28	3	0.22	3
29	2	0.15	3
30	1	0.07	3
31	137	10.04	3

SENSITIVITY LEVEL -  $V_{mirror}/V_{RPA}$

Sensitivity Level	8-bit $V_{mirror}/V_{RPA}$	Actual
0	0	0.0000
1	76	0.2980
2	86	0.3373
3	87	0.3412
4	89	0.3490
5	91	0.3569
6	95	0.3725
7	99	0.3882
8	105	0.4118
9	113	0.4431
10	123	0.4824
11	137	0.5373
12	155	0.6078
13	179	0.7020
14	212	0.8314
15	255	1.0000

## A P P E N D I X    B

## DEFAULT AUTOMATIC SENSITIVITY CONTROL ALGORITHM

Default Automatic Sensitivity Control determines if overcounting has occurred by examining the start and stop scalar values prior to deadtime correction. Each pair of energy steps is controlled independently of other pairs. (Step 30 is treated by itself, since step 31 is the charge-up energy step). If overcounting conditions are observed, the  $V_{\text{mirror}}/V_{\text{RPA}}$  for the two energy steps in the pair shall be adjusted to a lower sensitivity level defined in the current energy sweep table. For any given energy sweep table, there shall be a maximum of 16 sensitivity levels ( $V_{\text{mirror}}/V_{\text{RPA}}$ ) defined.

There are five thresholds associated with Default Automatic Sensitivity Control; four are called Scalar Thresholds, and the fifth is the Counting Threshold. The first step in the Default Control algorithm consists of examining all start and stop scalar values corresponding to an energy pair. The number of starts and stops exceeding each of the Scalar Thresholds (in the hierarchy of four Scalar Thresholds) is counted. If any of these counts exceed  $2 \times$  the Counting Threshold (or  $1 \times$  Counting Threshold for energy step 30), the sensitivity level is decreased according to the highest Scalar Threshold exceeded, as shown in the following table.

Scalar Threshold Number	Scalar Threshold (Default) Value	Number of Sensitivity Levels to Decrease
1	1533	1
2	1703	2
3	1803	3
4	1858	4

If the sensitivity level for a particular energy is at the lowest of the current 16 possible sensitivity levels and overcounting continues, the TOF supply shall be turned off. Finally, if overcounting persists for any of the energy steps after the TOF supply is turned off, the MCP supplies shall be turned off.

The default values of the Scalar Thresholds are shown in the table above. The default Counting Threshold is three. These thresholds may be altered via data load.

## OPTIONAL AUTOMATIC SENSITIVITY CONTROL ALGORITHM

If Optional Auto Sensitivity Control is enabled, start converts shall be examined independently for each pair of energy steps. If fewer than  $2 \times$  the counting threshold number of start converts for a particular pair of energy steps exceed Scalar Threshold-0, the corresponding sensitivity levels shall be increased by one. The default Scalar Threshold-0 value is 383. This may be changed by data load.

## A P P E N D I X    C

PROM MASS LOOK-UP TABLE ENTRY SPECIFICATIONS

<u>NUMBER</u>	<u>TOF RANGE</u>
0	1-7
1	8-25
2	26-41
3	42-70
4	71-105
5	106-130
6	106-156
7	157-254

## A P P E N D I X   D

## 16-BIT COMMAND DEFINITIONS FOR PSI

800X - Select analog multiplexer channel (X = 0 - D Hex)

9004 (1001 0000 0000 0100) - Heater PS on, level 1 (low)  
9006 (1001 0000 0000 0110) - Heater PS on, level 2  
9005 (1001 0000 0000 0101) - Heater PS on, level 3  
9007 (1001 0000 0000 0111) - Heater PS on, level 4 (high)  
9000 (1001 0000 0000 0000) - Heater PS off

A004 (1010 0000 0000 0100) - Discharge PS on, level 1 (low)  
A006 (1010 0000 0000 0110) - Discharge PS on, level 2  
A005 (1010 0000 0000 0101) - Discharge PS on, level 3  
A007 (1010 0000 0000 0111) - Discharge PS on, level 4 (high)  
A000 (1010 0000 0000 0000) - Discharge PS off

B004 (1011 0000 0000 0100) - Keeper PS on, level 1 (low)  
B005 (1011 0000 0000 0101) - Keeper PS on, level 2  
B006 (1011 0000 0000 0110) - Keeper PS on, level 3  
B007 (1011 0000 0000 0111) - Keeper PS on, level 4 (high)  
B000 (1011 0000 0000 0000) - Keeper PS off

CXXX (1100 XXXX XXXX XXXX) - 12-bit bias voltage control (000 - FFF)

D000 (1101 0000 0000 0000) - Valve on

E000 (1110 0000 0000 0000) - Valve off

For every command word that is transmitted to PSI a status data word is shifted into TIDE. The status data word is a 16-bit value that is defined as follows:

YXXX (YYYY XXXX XXXX XXXX) - Y = Mux address; X = 12-bit analog value from A/D converter

## A P P E N D I X    E

## DEAD TIME CORRECTION ALGORITHM

The dead time correction algorithm compares the start convert count for each energy step of each azimuthal sweep to a threshold of 33. If the start convert count is greater than or equal to this threshold, correction is made to the M/q data for the corresponding energy step and azimuth angle. There will, however, exist the option to disable dead time correction by uplink command. The dead time correction for M/q data shall be calculated as follows:

$$C_{true} = \frac{C_{observed}}{1 - \frac{\tau_d}{\tau_s} \times C_O^{SC}}$$

where

$C_{true}$  = *dead time corrected M/q count* ,

$C_{observed}$  = *observed M/q count* ,

$C_O^{SC}$  = *observed start convert count* ,

$\tau_s$  = *sample period* =  $5.27 \times 10^{-3}$  s ,

and

$\tau_d$  = *M/q dead time* =  $4.75 \times 10^{-6}$  s .

The correction to be performed for start singles is:

$$C_T^{Si} = \frac{C_O^{Si}}{1 - \frac{\tau_d}{\tau_s} \times C_O^{Si}}$$

where

$C_T^{Si}$  = *corrected start singles count for channel i* ( $1 \leq i \leq 7$ ) ,

$C_O^{Si}$  = *observed start singles count for channel i* ,

and

$\tau_d$  = *start singles dead time* =  $2.75 \times 10^{-6}$  s .

## A P P E N D I X F

### Lossy Compression Encoding

Input Range		Input Range		Input Range	
Minimum	Code	Minimum	Code	Minimum	Code
0	0	43	42	188	84
1	1	45	43	194	85
2	2	47	44	201	86
3	3	49	45	208	87
4	4	51	46	215	88
5	5	53	47	223	89
6	6	55	48	231	90
7	7	57	49	239	91
8	8	59	50	247	92
9	9	61	51	256	93
10	10	63	52	265	94
11	11	65	53	274	95
12	12	67	54	283	96
13	13	69	55	293	97
14	14	71	56	303	98
15	15	74	57	314	99
16	16	77	58	325	100
17	17	80	59	336	101
18	18	83	60	348	102
19	19	86	61	360	103
20	20	89	62	372	104
21	21	92	63	385	105
22	22	95	64	398	106
23	23	98	65	412	107
24	24	101	66	427	108
25	25	105	67	442	109
26	26	109	68	457	110
27	27	113	69	473	111
28	28	117	70	489	112
29	29	121	71	506	113
30	30	125	72	524	114
31	31	129	73	542	115
32	32	133	74	561	116
33	33	138	75	580	117
34	34	143	76	600	118
35	35	148	77	621	119
36	36	153	78	643	120
37	37	158	79	665	121
38	38	164	80	688	122
39	39	170	81	712	123
40	40	176	82	737	124
41	41	182	83	763	125

Input Range Minimum	Code	Input Range Minimum	Code	Input Range Minimum	Code
789	126	3552	170	16000	214
816	127	3680	171	16576	215
844	128	3808	172	17152	216
873	129	3936	173	17760	217
903	130	4064	174	18400	218
934	131	4192	175	19040	219
966	132	4352	176	19712	220
1000	133	4512	177	20416	221
1035	134	4672	178	21120	222
1071	135	4832	179	21856	223
1108	136	4992	180	22624	224
1147	137	5152	181	23424	225
1187	138	5344	182	24224	226
1228	139	5536	183	25056	227
1271	140	5728	184	25920	228
1315	141	5920	185	26816	229
1360	142	6112	186	27744	230
1407	143	6336	187	28704	231
1456	144	6560	188	29696	232
1507	145	6784	189	30752	233
1559	146	7008	190	31840	234
1613	147	7264	191	32960	235
1669	148	7520	192	34112	236
1727	149	7776	193	35296	237
1787	150	8032	194	36544	238
1849	151	8320	195	37824	239
1913	152	8608	196	39136	240
1979	153	8896	197	40512	241
2048	154	9216	198	41920	242
2112	155	9536	199	43392	243
2176	156	9856	200	44896	244
2240	157	10208	201	46464	245
2304	158	10560	202	48096	246
2400	159	10944	203	49760	247
2496	160	11328	204	51488	248
2592	161	11744	205	53280	249
2688	162	12160	206	55136	250
2784	163	12576	207	57056	251
2880	164	13024	208	59040	252
2976	165	13472	209	61120	253
3072	166	13952	210	63264	254
3168	167	14432	211	65504	255
3296	168	14944	212		
3424	169	15456	213		

## A P P E N D I X    G

## MOMENTS ALGORITHM

Approximations to the moments of the observed distributions will be derived from the dead-time corrected counts/sample. These include:

$$\bar{E} = \frac{\sum_i f_i \cdot \Delta E_i}{\sum_i R_i \cdot \Delta E_i}$$

where,

$$f_i = [G_F'(R_i) \cdot g(R_i) \cdot V_{RPA_i}]^{-1} \sum_j T(\theta_j) \sum_k C(E_i, \theta_j, \phi_k)$$

$$R_i = G_F'(R_i)^{-1} \sum_j T(\theta_j) \sum_k C(E_i, \theta_j, \phi_k)$$

$$\Delta E_i = g(R_{i+1}) \cdot V_{RPA_{i+1}} - g(R_{i-1}) \cdot V_{RPA_{i-1}}$$

$$T(\theta_j) = \frac{\sin(\theta_j)}{\epsilon(\theta_j)}$$

and,  $G_F'(R_i)$  and  $\epsilon(\theta_j)$  are defined by the relation,

$$G_F(R_i, \theta_j) = G_F'(R_i) \cdot \epsilon(\theta_j)$$

$V_{RPA_i}$  is the RPA step number.

The function,

$$g(R_i) = \frac{2}{[2 - F(R_i)]}$$

is defined such that,

$$E_i = g(R_i) \cdot V_{RPA_i}$$

with

$$F(R_i) = A \cdot (R_i - B)^\alpha$$

and A, B and  $\alpha$  are constants determined from laboratory testing.

In the azimuth and polar directions, centroids and boxcar widths will be calculated in terms of the respective data bin numbers. For the polar direction the centroid will be found for the distribution defined by,

$$z_j = T(\theta_j) \cdot \sum_i [G'_F(R_i)]^{-1} \sum_k C(E_i, \theta_j, \phi_k)$$

For the polar direction the distribution is defined by,

$$w_k = \sum_i [G'_F(R_i)]^{-1} \sum_j T(\theta_j) \cdot C(E_i, \theta_j, \phi_k)$$

In addition to the moment approximations several summations will be done within the moments module to provide checks on the efficiency of the detectors. These sums will be done on the Start Converts, Stops, Resets, and Time-outs.

## A P P E N D I X   H

## SERIAL COMMAND LIST

### Power Supply Commands

COMMAND CLASSIFICATION	OPCODE	COMMAND DESCRIPTION	BITS	EFFECTIVE
major serial	04	RPA HIGH VOLTAGE ENABLE		O/R
major serial	05	MIRROR HIGH VOLTAGE ENABLE		O/R
major serial	06	MCP 3.6 KV HIGH VOLTAGE ENABLE		O/R
major serial	07	MCP 2.4 KV HIGH VOLTAGE ENABLE		O/R
major serial	08	15 KV HIGH VOLTAGE ENABLE		O/R
major serial	0A	RPA HIGH VOLTAGE DISABLE		O/R
major serial	0B	MIRROR HIGH VOLTAGE DISABLE		O/R
major serial	0C	MCP 3.6 KV HIGH VOLTAGE DISABLE		O/R
major serial	0D	MCP 2.4 KV HIGH VOLTAGE DISABLE		O/R
major serial	0E	15 KV HIGH VOLTAGE DISABLE		O/R
minor	01	MCP 3.6 KV DAC UPDATE	16	SP
minor	02	MCP 2.4 KV DAC UPDATE	16	SP
minor	03	15 KV DAC UPDATE	16	SP
minor	04	ENERGY SWEEP TABLE SELECT	16	*
minor	05	ENERGY SWEEP TABLE FILL AND SELECT	24	SP
major serial	12	ENERGY SWEEP OPERATING TABLE SWAP	24	SP

\*Command parameter required to select execution on SP or SS2.

### Calibration Commands

COMMAND CLASSIFICATION	OPCODE	COMMAND DESCRIPTION	BITS	EFFECTIVE
major serial	2A	CAL PULSER SINGLE COMMANDING ENABLE		SP
minor	2A	CALIBRATION DELAY/REP RATE SELECT	16	PM
minor	2B	CALIBRATION TOF SECTOR SELECT	7	PM
major serial	2C	CAL PULSER SEQUENCE COMMANDING EN		SP
major serial	2D	CAL PULSER DISABLE		SP

### Microprocessor/Test/Diagnostic Commands

NOTE: These commands are for ground test only.  
 Do not attempt to execute commands when TIDE is operational.

COMMAND CLASSIFICATION	OPCODE	COMMAND DESCRIPTION	BITS	EFFECTIVE
major serial	31	CLEAR DIRECT EVENT MEMORY		SP
major serial	32	DIRECT EVENT BUFFER TOGGLE ENABLE		SP
major serial	33	DIRECT EVENT BUFFER 1 FREEZE (DIS. TOGGLING)		SSP
major serial	34	DIRECT EVENT BUFFER 2 FREEZE		SSP
major serial	35	M/q DATA BUFFER TOGGLE ENABLE		SP
major serial	36	M/q DATA BUFFER 1 FREEZE		SSP
major serial	37	M/q DATA BUFFER 2 FREEZE		SSP

### Instrument Operations Commands

COMMAND CLASSIFICATION	OPCODE	COMMAND DESCRIPTION	BITS	EFFECTIVE
major serial	38	WATCHDOG ENABLE		O/R
major serial	39	WATCHDOG DISABLE		O/R
major serial	40	S/C SPIN SUN PULSE LOCK		O/R
major serial	41	S/C SPIN FREE-RUN MODE		O/R
minor	42	CONSTANT PHASE SHIFT (SPIN OFFSET) EN	8	SS2
major serial	43	PHASE SHIFT (SPIN OFFSET) DISABLE		SS2
major serial	75	EXECUTE STORED SSPIN COMMANDS		O/R
major serial	77	HIGH ANGULAR RESOLUTION MODE ENABLE		SS2
major serial	78	HIGH ANGULAR RESOLUTION MODE DISABLE		SS2
major serial	72	DUMP MODE ENABLE (IMP)		SS2
major serial	73	DUMP MODE ENABLE (DP)		SS2
minor	72	ADDRESS FOR MEMORY DUMP	24	PM
major serial	74	CLEAR IMP/DP ERROR FLAGS		O/R
major serial	7D	DEFAULT AUTO SENSITIVITY CONTROL ENABLE		SP
major serial	7E	OPTIONAL AUTO SENSITIVITY CONTROL ENABLE		SP
major serial	7F	AUTO SENSITIVITY CONTROL DISABLE		SP
major serial	79	HAR MODE PHASE SHIFT SWELL	5	PM

### Mass Look-Up Table Commands

COMMAND CLASSIFICATION	OPCODE	COMMAND DESCRIPTION	BITS	EFFECTIVE
major serial	52	MASS LUT SWAP		SS2
major serial	53	LOAD THE POWER-UP DEFAULT TABLE		SS2
minor	50	MASS LUT ENTRY SPECIFICATION	24	PM
minor	51	MASS LUT BUILD	20	SS2

### Data Processing Commands

COMMAND CLASSIFICATION	OPCODE	COMMAND DESCRIPTION	BITS	EFFECTIVE
major serial	80	DEAD TIME CORRECTION ENABLE		SS2
major serial	81	DEAD TIME CORRECTION DISABLE		SS2
major serial	60	RICE COMPRESS ENABLE		SS2
major serial	61	RICE COMPRESS DISABLE		SS2
major serial	86	TRUNCATED REPORTING		SS2
minor	86	COMPLETE REPORTING OF FIXED IONS	5	SS2
minor	87	COMPLETE REPORTING WITH ROTATING IONS	5	SS2
minor	88	COLLAPSE OPTION/CALIBRATION MODE	8	SS2
minor	89	HIGH TIME RES. MODE ENABLE	24	SP
major serial	89	HIGH TIME RES. MODE TRIGGER DISABLE		SP
minor	8B	PRIORITY ORDERING	24	SS2
major serial	44	MOMENTS CALCULATION ENABLE		SP
major serial	45	MOMENTS CALCULATION DISABLE		SP
major serial	48	DE SECTOR 0 DATA DISABLE		SSP
major serial	49	DE SECTOR 0 DATA ENABLE		SSP

NOTE: O/R - on receipt  
SP - spin boundary execution  
SSP - Superspin boundary execution  
SS2 - Execute stored command required for execution. One full superspin occurs before command execution.  
PM - parameter - other command(s) are required to use this parameter.

## SERIAL COMMAND FORMATS

### RPA High Voltage Enable

Mirror High Voltage Enable

### MCP 3.6 KV High Voltage Enable

#### MCP 2.4 KV High Voltage Enable

#### 15 KV High Voltage Enable

### BPA High Voltage Disable

Mirror High Voltage Disable

MCP 3.6 KV High Voltage Disable

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		

MCP 2.4 KV High Voltage Disable

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/			

15 KV High Voltage Disable

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		

MCP 3.6 KV DAC Update

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	/	/	/	/				

VVVVVVVV = DAC update value. Note that this 8-bit value is in the command twice to guard against onboard software loading the power supply register with a corrupted value.

MCP 2.4 KV DAC Update

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	V	V	V	V	V	V	V	V	V	V	V	V	V	V	/	/	/	/				

VVVVVVVV = DAC update value. Note that this 8-bit value is in the command twice to guard against onboard software loading the power supply register with a corrupted value.

15 KV DAC Update

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	V	V	V	V	V	V	V	V	V	V	V	V	V	V	/	/	/	/				

VVVVVVVV = DAC update value. Note that this 8-bit value is in the command twice to guard against onboard software loading the power supply register with a corrupted value.

Energy Sweep Table Select

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	N	N	N	0	0	0	0	0	0	E	/	/	/	/	/	/	/	/	/	/

NNN = table number (tables 0 - 4 are in ROM, tables 5 - 6 are in RAM)  
E = execution (0 = superspin boundary, 1 = spin boundary)

Energy Sweep Table Fill and Select

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	1	M	M	M	M	M	M	M	M	M	M	M	M	M	M	R	R	R	R	R	R	R	R	R	R

MMMMMM = mirror/RPA value (0-255)  
RRRRRRRRRRRR = RPA value (0-4095)

Calibration Pulser Single Commanding Enable

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	0	0	1	0	1	0	1	0	1	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		

Calibration Delay/Repetition Rate Select

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	0	1	0	1	0	1	0	D	D	D	D	0	0	0	0	R	R	R	R	/	/	/	/	/	/	/	/	/	/		

DDD = DELAY RATE			RRRR = REP RATE		
command	code	value	command	code	value
0		0 nsec	0		62.5 kHz
1		10 nsec	1		66.6 kHz
2		40 nsec	2		71.4 kHz
3		80 nsec	3		76.9 kHz
4		120 nsec	4		83.3 kHz
5		160 nsec	5		90.9 kHz
6		200 nsec	6		100.0 kHz
7		240 nsec	7		111.1 kHz
			8		125.0 kHz
			9		142.9 kHz
			A		166.7 kHz
			B		200.0 kHz
			C		250.0 kHz
			D		333.3 kHz
			E		500.0 kHz
			F		1.0 mHz
					ct./sample period
					330
					351
					377
					406
					439
					479
					527
					586
					659
					754
					879
					1055
					1317
					1758
					2637
					5273

### Calibration TOF Sector Select

if  $S_x = 0$ , sector  $x$  not selected  
if  $S_x = 1$ , sector  $x$  selected

### Calibration Pulser Sequence Commanding Enabled

#### Calibration Pulser Disable

### Energy Sweep Operating Table Swap

### **Clear Direct Event Memory Command**

### Direct Event Buffer Toggle Enable Command

### Direct Event Buffer 1 Freeze Command

## Direct Event Buffer 2 Freeze Command

## M/q Data Buffer Toggle Enable Command

### M/q Data Buffer 1 Freeze Command

### M/q Data Buffer 2 Freeze Command

### Watchdog Enable Command

### Watchdog Disable Command

## Dump Mode Enable (TMR) Command

#### Dump Mode Enable (DP) Command

## Memory Dump Address Command

AAAAAAAAAAAAAAA = dump start address (20-bit)

### **Clear IMP/DP Error Flags Command**

### S/C Spin Sun Pulse Lock Command

### S/C Spin Free-Run Mode Command

Constant Phase Shift (Spin Offset) Enable Command

PPPPPPPPP = constant offset (0 - 255 corresponding to 0° - 22.5°)

### Phase Shift (Spin Offset) Disable Command

## Execute Stored SSpin Commands Command

## High Angular Resolution Mode Enable Command

## High Angular Resolution Mode Disable Command

### HAB Mode Phase Shift Dwell Command

NNNN = number of spins to remain at each phase shift when in High Angular Resolution Mode.

## Default Auto Sensitivity Control Enable Command

Optional Auto Sensitivity Control Enable Command

#### Auto Sensitivity Control Disable Command

## Mass Look-Up Table Swap Command

#### **Power-Up Default Mass Look-Up Table Load Command**

## Mass Look-Up Table Entry Specification Command

RRR = RAM entry specification number (0 - 7)

SSSSSSSS = start TOF channel number (0 - 255)  
EEEEEEEEE = stop TOF channel number (0 - 255)

## Mass Look-Up Table Build Command

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	0	1	0	1	0	0	0	1	/	/	/	/	N <sub>0</sub>	N <sub>0</sub>	N <sub>0</sub>	N <sub>0</sub>	N <sub>1</sub>	N <sub>1</sub>	N <sub>1</sub>	N <sub>1</sub>	N <sub>2</sub>	N <sub>2</sub>	N <sub>2</sub>	2	N <sub>3</sub>	N <sub>3</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>4</sub>	N <sub>4</sub>		

$N_xN_xN_xN_x$  = number of description for mass x (0 - 15). Descriptions 0 - 7 are in ROM, and descriptions 8 - 15 are in RAM.

### Dead Time Correction Enable Command

### Dead Time Correction Disable Command

## Rice Compression Enable Command

### Rice Compression Disable Command

### Truncated Reporting Command

## Complete Reporting of Fixed Ions Command

**Mx** = Mx if set indicates that mass x is to be included in the complete reporting

## Complete Reporting with Rotating Ions Command

Mx = the four Mx's which are set indicate the four minor ions that shall be rotated, so that, for each complete report, one of these minor ions shall be reported with the other two ions (major ions) which are always reported.

#### Collapse Option/Calibration Mode Command

CCC = collapse option ( $\theta = 6$ )

#### High Time Resolution Mode Enable Command

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	1	1	0	0	0	1	0	0	1	/	/	/	/	O	E	H	M	/	/	/	S	S	S	S	/	/	/	D	D	D	D		

E	= EFI trigger mask (0 = EFI not a trigger, 1 = EFI contributes to a valid trigger)
H	= Hydra trigger mask (0 = Hydra not a trigger, 1 = Hydra contributes to a valid trigger)
M	= moment trigger mask (0 = moment variability will not trigger high time resolution, 1 = moment variability contributes to a valid trigger)
O	= AND/OR of the selected E, H, M signals. The Boolean operator (0 = AND ; 1 = OR) is applied to all of the signals (EFI, Hydra, Moment Variability) which are selected in their corresponding mask field with a one. If the result is one, the High Time Resolution Mode is triggered.)
SSSS	= number of standard deviations. If the moment results vary from the history of moment results by $\geq$ SSSS standard deviations, this contributes to a valid trigger if M is set.
DDDD	= number of complete superspins that the instrument dwells in High Time Resolution Mode. (Since HTR Mode may begin on any spin boundary, the mode will typically last for DDDD.FFF superspins, where FFF is some fraction of a superspin.

NOTE: If the E, H, and M flags are all zero, then this command shall automatically trigger high time resolution for the specified dwell period.

### High Time Resolution Mode Trigger Disable

### Priority Ordering Command

39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
1	0	1	1	0	0	0	1	1	0	0	0	1	0	1	1	1	S	M <sub>0</sub>	M <sub>0</sub>	M <sub>0</sub>	O	M <sub>1</sub>	M <sub>1</sub>	M <sub>1</sub>	O	M <sub>2</sub>	M <sub>2</sub>	M <sub>2</sub>	O	M <sub>3</sub>	M <sub>3</sub>	M <sub>3</sub>	O	M <sub>4</sub>	M <sub>4</sub>	M <sub>4</sub>	O	M <sub>5</sub>	M <sub>5</sub>	M <sub>5</sub>

S = priority ordering scheme  
 (0 = complete masses are reported in the requested order,  
 1 = detectors 4 and 5 data are reported for each mass, followed  
 by detectors 1, 2, and 3 data for each mass, followed by  
 detectors 6 and 7 data for each mass. Masses are still  
 reported in the requested order.)  
 $M_0 M_0 M_0$  = mass to be reported first (0 - 5; 5 indicates the singles "mass")  
 $M_1 M_1 M_1$  = mass to be reported second (0 - 5)

### Moments Calculation Enable Command

Moments calculation Disable Command

DE sector 0 Data Enable

DE sector 0 Data Disable

## A P P E N D I X    I

#### HOUSEKEEPING DATA

<u>MiFr No. (0-249)</u>	<u>Byte No.</u>	<u>Description</u>	<u>Mnemonic</u>
5	11	Major Frame count	TMAFRCNT
5	12	Command counter	TCMD_CNT
17	11	Power supply status	TPWR_STX
17	12	System status 1	TSYSST1X
29	12	IMP status	TIMP_STX
41	12	DP status	T_DP_STX
53	11	System status 2	TSYSST2X
53	12	System status 3	TSYSST3X
*	61	Input current	TINPCURR
65	11	PSI Bias current	TPBSCURR
65	12	TOF DAC adjust	TTOFDACA
77	11	PSI status 1	TPSIST1X
77	12	3.6KV DAC adjust	T36KDACA
*	79	+5V monitor	T_P5VMON
*	85	Temperature 1	T_TEMP_1
89	11	PSI status 2	TPSIST2X
89	12	2.4 KV DAC adjust	T24KDACA
*	91	Temperature 2	T_TEMP_2
*	97	PSI temperature 1	TP_TEMP1
101	12	-15 KV monitor	T15KVMON
*	103	PSI temperature 2	TP_TEMP2
113	11	PSI keeper voltage	TPKEEPRV
113	12	-3.6KV monitor	T36KVMON
125	11	PSI keeper current	TPKEEPRI
125	12	-2.4 KV monitor	T24KVMON
134	11	Temperature 4	T_TEMP_4
137	11	PSI filament voltage	TPFILMTV
137	12	+3 V monitor	T_P3VMON
149	11	PSI filament current	TPFILMTI
149	12	Temperature 3	T_TEMP_3
161	11	PSI discharge voltage	TPDISCHV
161	12	Flash ADC monitor	TFADCMON
173	11	PSI discharge current	TPDISCHI
173	12	+15 V monitor	T_P15VMN
185	11	PSI hi gas pressure	TPHIGASP
185	12	+10 V monitor	T_P10VMN
197	11	PSI lo gas pressure	TPLOGASP
197	12	+10 V DAC reference	T10VREFV
209	11	PSI +5 V monitor	TPP5VMON
209	12	10V DAC temperature ref	T10VREFT
221	11	PSI +15V monitor	TPP15VMN
221	12	Power supply temperature	TTEMP_PS
233	11	PSI +28V current	TPP28V_I
233	12	DP temperature	TTEMP_DP
245	11	RPA peak voltage monitor	T300VRPA
245	12	MIR peak voltage monitor	T450VMIR

#### HOUSEKEEPING STATUS BYTE DEFINITIONS

Power supply status:

<u>Bit</u>	<u>Description</u>	<u>Mnemonic</u>
0 (LSB)	15 KV enable (0=disable, 1=enable)	T15KVENA
1	3.6 KV enable (0=disable, 1=enable)	T36KVENA
2	2.4 KV enable (0=disable, 1=enable)	T24KVENA
3	RPA enable (0=disable, 1=enable)	TRPA_ENA
4	MIR enable (0=disable, 1=enable)	TMIR_ENA
5	15 KV Arm (0=safe, 1=arm)	T15KVARM
6	2.4/3.6 KV Arm (0=safe, 1=arm)	T2436ARM
7	RPA/MIR Arm (0=safe, 1=arm)	TRPMIARM

System status 1:

0 (LSB)	Auto sensitivity (0=default, 1=optional)	TAUTOSEN
1	Watchdog (0=disable, 1=enable)	TWATCHDG
2	Hardware arm status bit 0 (0=safe, 1=1/10, 2=N/A, 3=arm)	T_HVSTAT
3	Hardware arm status bit 1	
4	PSI Squirt (0=off, 1=on)	TPSQUIRT
5	Pulser status (0=off, 1=on)	TPULSSTA
6	Boot mode (0=normal, 1=alternate ROM)	TBOOTMOD
7	Auto sensitivity (0=disable, 1=enable)	TAUTOENA

System status 2:

0 (LSB)	Command received (0=OK, 1=error)	TCMD_REC
1	Command executed (0=OK, 1=error)	TCMD_EXE
2	Data load (0=OK, 1=error)	TDATA_LD
3	Telemetry queue (0=OK, 1=error)	TTLM_QUE
4	Telemetry (0=invalid, 1=valid)	TTLMSTAT
5	DE memory (0=OK, 1=error)	T_DE_MEM
6	PSI status (0=OK, 1=error)	TPSISTAT
7	spare	

System status 3:

0 (LSB)	Super spin counter bit 0 (lsb)	TSS_CNT
1	Super spin counter - bit 1	
2	Super spin counter - bit 2	
3	Instrument mode - bit 0 (lsb) - (00-Dump, 01-Debug)	TINSMODE
4	Instrument mode - bit 1 - (10-Science, 11-Undefined)	
5	TLM mode - bit 0 (lsb) - (00-Science, 01-Engineering 10-Maneuver, 11-Contingency)	TLMMODE
6	TLM mode - bit 1	
7	Mode change pending (0=no, 1=yes)	TCHG_PEN

**IMP status:**

0 (LSB)	RAM memory (0=OK, 1=error)	TIMP_RAM
1	ROM memory (0=OK, 1=error)	TIMP_ROM
2	Shared memory (0=OK, 1=error)	TIMP_SHAR
3	MLUT (0=OK, 1=error)	TIMPMLUT
4	Energy sweep (0=OK, 1=error)	TIMPESWP
5	Debug initiated (0=no, 1=yes)	TDBGINIT
6	Acquisition mode (0=Sun, 1=Free)	TSUNMODE
7	Data processor health (0=OK, 1=Error)	TDPHEALT

**DP status:**

0 (LSB)	DP RAM memory (0=OK, 1=Error)	TDP_RAM
1	DP ROM memory (0=OK, 1=Error)	TDP_ROM
2	DP Shared memory (0=OK, 1=Error)	TDP_SHRD
3	DP data acq memory (0=OK, 1=Error)	TDPDATMS
4	DP command (0=OK, 1=Error)	TDP_CMD
5	DP deadtime correction overflow (0=OK, 1=Error)	
6	DP mode - bit 0 (lsb) (0=dump, 1=eng., 2=sci, 3=cal)	TDPMODE
7	DP mode - bit 1	

**PSI status 1:**

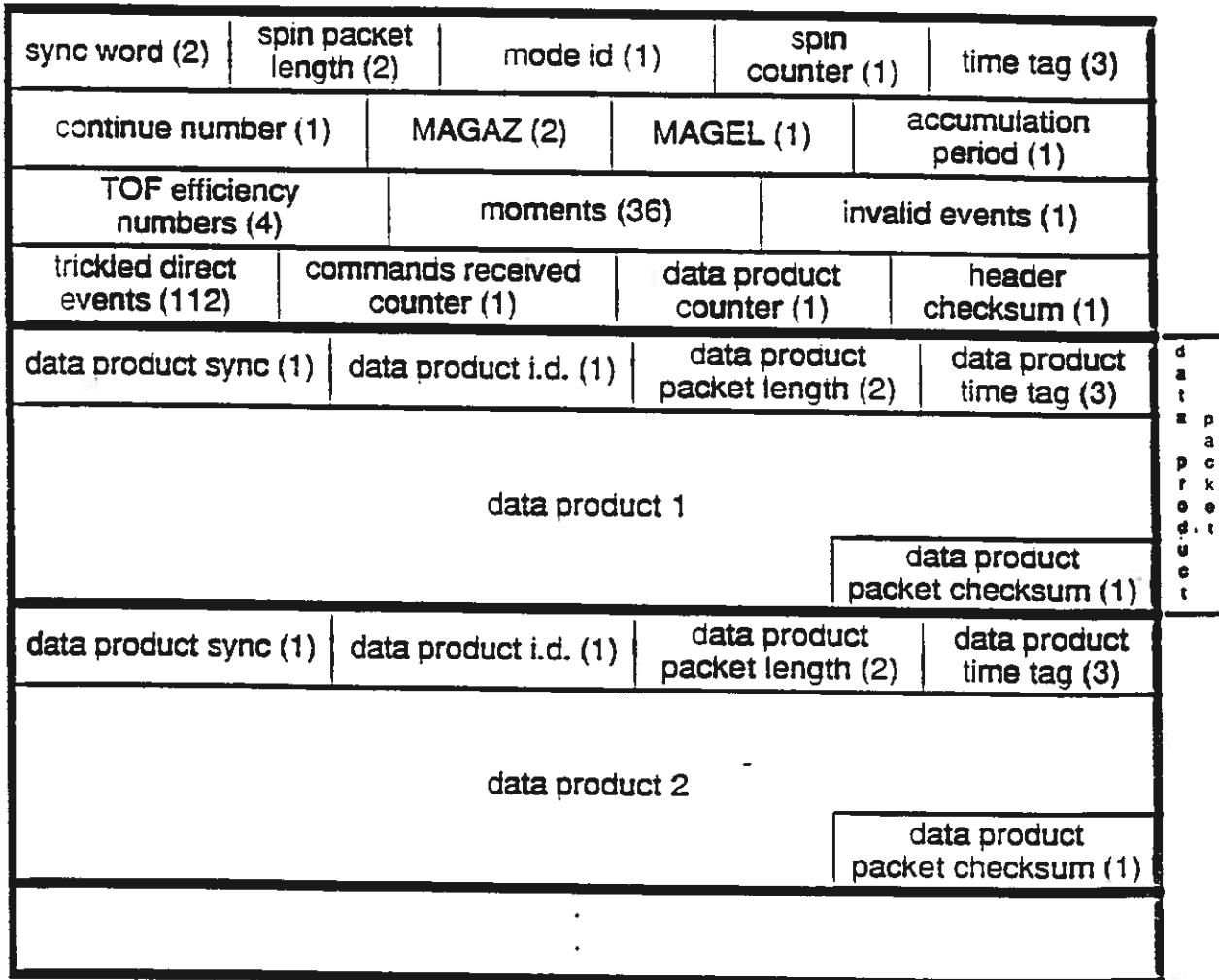
0 (LSB)	Bias current - bit 8	TPBSCUR1
1	Bias current - bit 9	
2	Bias current - bit 10	
3	Bias current - bit 11	
4	Heater control level - bit 0 (lsb) (xx = lo, yy=hi)	TPHEATLV
5	Heater control level - bit 1	
6	Heater (0=off, 1=on)	TPHEATST
7	PSI arm (0=safe, 1=arm)	TPSI_ARM

**PSI status 2:**

0 (LSB)	Discharge control level - bit 0 (lsb) (xx=lo, yy=hi)	TPDISCLV
1	Discharge control level - bit 1	
2	Discharge (0=off, 1=on)	TPDISCST
3	Keeper control level - bit 0 (lsb) (xx=lo, yy=hi)	TPKEEPLV
4	Keeper control level - bit 1	
5	Keeper (0=off, 1=on)	TPKEEPST
6	Valve 1 status (0=off, 1=on)	TPVLVST1
7	Valve 2 status (0=off, 1=on)	TPVLVST2

## A P P E N D I X   J

### TIDE Spin Packet Format



#### Notes:

- Numbers in () represent the number of bytes required.
- Spin packet length word will contain the number of bytes in the packet. This does not include fill pattern bytes, which are not part of a packet, but may be present between packets.
- The first time tag corresponds to the spin counter, accumulation period, MAGAZ, MAGEL, efficiency numbers, and moments. The other time tags correspond to the data reported in the data product packets.
- A complete table of instrument parameters is telemetered as the first data product in the first spin packet of every superspin. On subsequent spins, instrument parameter changes will be reported in the first data product of the spin packet, only if any of the parameters have changed since the beginning of the superspin.

## A P P E N D I X   K

INSTRUMENT PARAMETERS DATA PRODUCT CONTENTS

<u>PARAMETER</u>	<u>NO. BITS</u>	<u>NO. BYTES</u>	<u>PARAM. LIST POSITION</u>	<u>BYTE(S)</u>	<u>BIT(S)</u>
15 kV power supply value	8	1	0		0-7
3.6 kV power supply value	8	1	1		0-7
2.4 kV power supply value	8	1	2		0-7
15 kV power supply dis/en	1	<1	3		0
3.6 kV power supply dis/en	1	<1	3		1
2.4 kV power supply dis/en	1	<1	3		2
RPA power supply dis/en	1	<1	3		3
mirror power supply dis/en	1	<1	3		4
high voltage dis/en (arm)	1	<1	3		5
MCP dis/en (arm)	1	<1	3		6
RPA and mirror dis/en (arm)	1	<1	3		7
flyback step indicators (8bits x 4)	32	4	4-7		0-7,0-7,...
mirror/RPA power supply values (8bits x 31)	248	31	8-38		0-7,0-7,...
RPA power supply values (12bits x 31)	372	46.5	39-85		
(Each pair of RPA values is stored in 3 bytes, such that values appear highest bit to lowest bit in the telemetry bit stream. For example, byte 39 will contain the highest order byte of energy 0. The high order nibble of byte 40 will contain the low order nibble of energy 0, and the low order nibble of byte 40 will contain the high order nibble of energy 1. Byte 41 will contain the low order byte of energy 1.)					
auto sensitivity control dis/en	1	<1	85		0
auto sensitivity control default/optional	1	<1	85		1
ESWEEP table format (auto sensitivity/cal)	1	<1	85		2
moments dis/en	1	<1	85		3
*(if auto sensitivity enabled)					
scalar threshold 0	16	2	86-87 <sup>+</sup>		0-15
scalar threshold 1	16	2	88-89 <sup>+</sup>		0-15
scalar threshold 2	16	2	90-91 <sup>+</sup>		0-15
scalar threshold 3	16	2	92-93 <sup>+</sup>		0-15
scalar threshold 4	16	2	94-95 <sup>+</sup>		0-15
count threshold	8	1	96		0-7

\* The condition for which the following parameter is relevant.

+ Low order byte is first.

<u>PARAMETER</u>	<u>NO. BITS</u>	<u>NO. BYTES</u>	<u>PARAM. LIST POSITION</u>	<u>BYTE(S)</u>	<u>BIT(S)</u>
*(if ESWEEP table format = auto sensitivity)					
8 mirror/RPA ratios (8bits x 8)	64	8	97-104	0-7,0-7,...	
start and stop TOF channel #s for MLUT (8bits x 2 x 5)	80	10	105-114	0-7,0-7,...	
energy remapping table number	3	<1	115	0-2	
angle remapping table number	3	<1	115	3-5	
cal pulser state (2 bits => 0=dis, 1=single commanding 2=sequence commanding)	2	<1	115	6-7	
*(if cal pulser state = 1)					
delay	3	<1	116	0-2	
UNUSED	1	<1	116	3	
rep rate	4	<1	116	4-7	
sector select	7	<1	117	0-6	
UNUSED	1	<1	117	7	
*(if high time resolution triggers enabled)					
number of standard deviations for moment trigger	4	<1	118	0-3	
number of complete superspins to dwell in High Time Resolution Option	4	<1	118	4-7	
UNUSED	5	<1	119	0-4	
*(if high time resolution triggers enabled)					
high time res moment trigger (did not occur/occurred)	1	<1	119	5	
high time res Hydra trigger (did not occur/occurred)	1	<1	119	6	
high time res EFI trigger (did not occur/occurred)	1	<1	119	7	
UNUSED	16	2	120-121		
UNUSED	1	<1	122	7	
direct event buffer freeze dis/en	1	<1	122	6	
*(if direct event buffer freeze enabled)					
frozen buffer (1/2)	1	<1	122	5	
M/q data buffer freeze dis/en	1	<1	122	4	
*(if M/q data buffer freeze enabled)					
frozen buffer (1/2)	1	<1	122	3	
watchdog dis/en	1	<1	122	2	
s/c sun pulse lock/free run	1	<1	122	1	
UNUSED	1	<1	122	0	
current phase shift	8	1	123	0-7	
UNUSED	3	<1	124	5-7	
*(if high angular res phase shift enabled)					
number of spins to remain at each phase shift	5	<1	124	0-4	
UNUSED	2	<1	125	6-7	
dead time correction dis/en	1	<1	125	5	
UNUSED	2	<1	125	3-4	
collapse option	3	<1	125	0-2	
UNUSED	6	<1	126	0-5	
Rice compression dis/en	1	<1	126	6	
truncated/complete reporting	1	<1	126	7	

<u>PARAMETER</u>	<u>NO. BITS</u>	<u>NO. BYTES</u>	<u>PARAM. LIST POSITION</u>	<u>BYTE(S)</u>	<u>BIT(S)</u>
*(if complete reporting)					
ions always reported	6	<1	127	0-5	
fixed set of ions/rotated minor ions	1	<1	127	6	
priority reporting order scheme (0/1)	1	<1	127	7	
first priority mass	3	<1	128	0-2	
second priority mass	3	<1	128	3-5	
UNUSED	2	<1	128	6-7	
third priority mass	3	<1	129	0-2	
fourth priority mass	3	<1	129	3-5	
UNUSED	1	<1	129	6	
high time resolution triggers dis/en	1	<1	129	7	
fifth priority mass	3	<1	130	0-2	
sixth priority mass	3	<1	130	3-5	
high time resolution processing dis/en	1	<1	130	6	
high angular resolution mode dis/en	1	<1	130	7	
*(if ESWEEP table format = auto sensitivity)					
8 mirror/RPA ratios (8bits x 8)	64	8	131-138	0-7,0-7,...	
moment trigger for High Time Resolution Option (not a trigger/can contribute to valid trigger)	1	<1	139	0	
Hydra trigger for High Time Resolution Option (not a trigger/can contribute to valid trigger)	1	<1	139	1	
EFI trigger for High Time Resolution Option (not a trigger/can contribute to valid trigger)	1	<1	139	2	
method of determining when to initiate High Time Resolution Option (AND triggers/OR triggers)	1	<1	139	3	
Hydra burst signal (low to high transition)	1	<1	139	4	
Hydra burst signal (high to low transition)	1	<1	139	5	
EFI burst signal (low to high transition)	1	<1	139	6	
EFI burst signal (high to low transition)	1	<1	139	7	

## INSTRUMENT PARAMETER CHANGES DATA PRODUCT

Subset(s) of the following instrument parameters shall be reported in the Instrument Parameters Change Data Product. The parameters listed below are the only parameters which may legally change at a spin boundary which is not a superspin boundary.\* If no changes have been made to the instrument parameters during a spin, then the Instrument Parameter Change Data Product will not be reported. If a change of any of the parameters in Group 1 below occurs, then the entire Group 1 information shall be reported. If a change of any of the mirror/RPA ratios occurs then Group 1, followed by Group 2 shall be reported. If a change of any of the RPA values occurs, then Group 1, Group 2, and Group 3 shall be reported.

\* Actually there may be a few other parameters which are allowed to change on the spin boundary for calibration only.

<u>PARAMETER</u>	<u>NO. BITS</u>	<u>NO. BYTES</u>	<u>PARAM. LIST POSITION</u>	<u>BIT(S)</u>
<b>*****GROUP1*****</b>				
15 kV power supply dis/en	1	<1	0	0
3.6 kV power supply dis/en	1	<1	0	1
2.4 kV power supply dis/en	1	<1	0	2
RPA power supply dis/en	1	<1	0	3
mirror power supply dis/en	1	<1	0	4
ESWEEP table format (auto sensitivity/cal)	1	<1	0	5
auto sensitivity control dis/en	1	<1	0	6
auto sensitivity control default/optional	1	<1	0	7
moments dis/en	1	<1	1	0
spacecraft pulse lock/free run mode	1	<1	1	1
watchdog dis/en	1	<1	1	2
number of complete superspins to dwell in High Time Resolution Option	4	<1	1	3-6
high time resolution triggers dis/en	1	<1	1	7
collapse option	3	<1	2	0-2
truncated/complete reporting	1	<1	2	3
high time resolution processing dis/en	1	<1	2	4
*(if high time resolution triggers enabled)				
high time res moment trigger (did not occur/occurred)	1	<1	2	5
high time res Hydra trigger (did not occur/occurred)	1	<1	2	6
high time res EFI trigger (did not occur/occurred)	1	<1	2	7
15 kV power supply value	8	1	3	0-7
3.6 kV power supply value	8	1	4	0-7
2.4 kV power supply value	8	1	5	0-7
current phase shift	8	1	6	0-7
method of determining when to initiate High Time Resolution Option (AND triggers/OR triggers)	1	<1	7	0
moment trigger for High Time Resolution Option (not a trigger/can contribute to valid trigger)	1	<1	7	1

<u>PARAMETER</u>	NO. BITS	NO. BYTES	PARAM. BYTE(S)	LIST POSITION BIT(S)
Hydra trigger for High Time Resolution Option (not a trigger/can contribute to valid trigger)	1	<1	7	2
EFI trigger for High Time Resolution Option (not a trigger/can contribute to valid trigger)	1	<1	7	3
Hydra burst signal (low to high transition)	1	<1	7	4
Hydra burst signal (high to low transition)	1	<1	7	5
EFI burst signal (low to high transition)	1	<1	7	6
EFI burst signal (high to low transition)	1	<1	7	7
*****				
*****GROUP2*****				
mirror/RPA power supply values (8bits x 31)	248	31	8-38	0-7,0-7,...
*****				
*****GROUP3*****				
RPA power supply values (12bits x 31)	372	46.5	39-85	
*****				